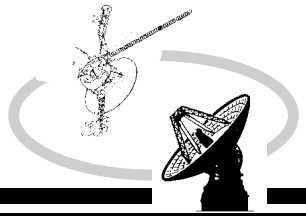
Radio Metric Tracking

Stephen M. Lichten

TMO Technology Program Quarterly Review

January, 1998

Radio Metric Tracking
Objective and Significance

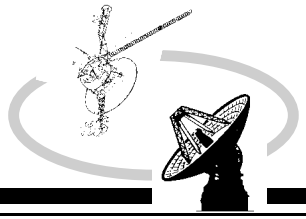


Overall Objective

Develop new technologies to enable fully autonomous navigation and spacecraft operations. Reduce operational costs and improve accuracy of radio metric tracking techniques used for trajectory determination and science applications.

Goals	Significance
• "GPS-Derivative Navigation" (GDN) technology thrust to develop and demonstrate autonomous spacecraft tracking and communications systems for deep space missions	• Autonomous in situ multimission navigation for Mars missions, New Millennium Program • Can lower NASA tracking operations costs by order of magnitude
• GPS technology development: global Wide Area Differential GPS (WADGPS), and GPS space receivers	• Enables low-cost, autonomous onboard navigation of Earth orbiters; potential for onboard generation of science products with significant cost savings
• Transfer highly automated prototype GPS calibration system	• Frees up 1000 hrs/yr for 70-m antennas valued at $3M/yr.
• Improve interplanetary frame tie	• Reduce navigation costs and fuel margins, increase science return
• Transfer new GPS technologies to private and government sectors	• Shows critical contributions from NASA to technologies of societal importance

Radio Metric Tracking
Products and Customers



Product	*User/Customer*	*Development Phase*				*Approach/Comments*
		Concept	Design	Demo	Transfer	
Fully autonomous, in situ nav systems for planetary missions; autonomous formation flyer (AFF); rendezvous navigation	Suite of Mars missions; DS-3; DS-4; deep space interferometry missions; rendezvous missions	■	■			Develop system architecture, AFF sensor & s/w
Low-power new space GPS receivers for autonomous spacecraft	NASA/Code O Military & commercial	■	■	■		μGPS flight demos: SNOE and STRV. Enable fully autonomous spacecraft navigation and control
Autonomous Wide Area Differential GPS (WADGPS) navigation for Earth orbiters	NASA Earth orbiters (Nav); commercial & military users	■	■	■	■	Quantify NASA performance, and cost/benefit trades; develop system architecture and perform demos; tech transfer to private sector/FAA
Planetary frame tie	Nav; science teams		■	■	■	Delivered to ephemeris team.
Earth orientation calibrations, DSN troposphere path delays, precise DSN time transfer	Nav; Flight projects; Freq/timing group				■	Free up 1000 hrs/yr 70-m antenna time; transfer to ops in FY98

Radio Metric Tracking
The "Big" Picture

Fill Codes:
- Flight
- Ground
- Flight & Ground

Check all that apply:
- ☑ Automation
- ☑ Autonomy
- ❑ GSE
- ☑ Development
- ☑ Operations
- ☑ Flight
- ☑ Ground
- ☑ H/W
- ☑ S/W
- ❑ Protocol
- ☑ Testbed

Avionics

Instrument

Telecom & Relay

Schedule

Nav & Trk

Plan & Seq

Miss Des

Analyze

Rcvr

Cmnd

Ant / Optics

Networks

Eng Proc

Visualize

Xmtr

Telemetry

Data Mgmt

Sci Proc

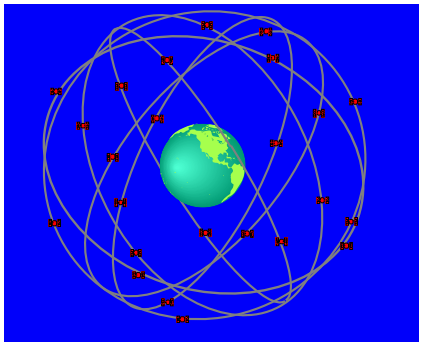
Data Prod

Other Infra

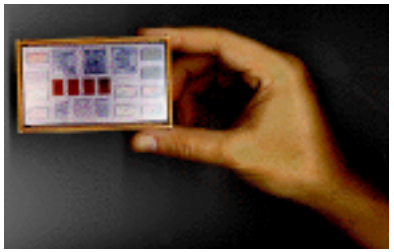
Mon & Cntrl

Radio Metric Tracking
Relevant Technical Skills

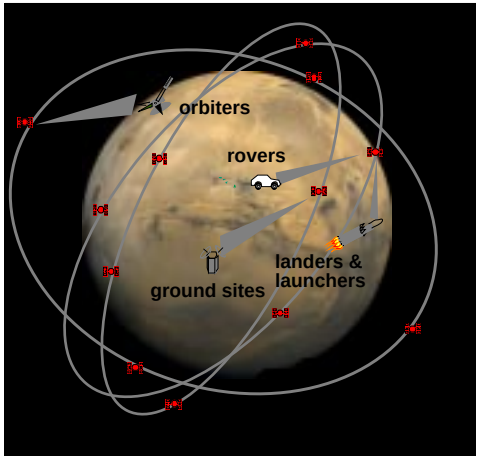
- **Earth orbiter tracking and navigation**
  - **Fully automated: real-time and post-process**
  - **Precise GPS orbit determination**
  - **Precise user positioning: near-Earth regime, low-Earth to high-Earth orbiters**
  - **Wide Area Differential GPS (WADGPS)**
  - **Precise Earth platform parameter estimates: orientation, atmosphere, & time-transfer**
- **Precise planetary reference-frame determination and calibration**
  - **VLBI and same-beam VLBI; Doppler & range**
- **Tracking, navigation and telecom: hardware & software systems, design & development for planetary missions**
  - **RF-receive and transmit instrumentation**
  - **GPS receivers and derivative transceivers**
  - **Tracking and navigation algorithms**
  - **AFF: Autonomomous Formation systems for precision two-way tracking & telecom**
  - **Embedded real-time systems (onboard)**
  - **Autonomous spacecraft**



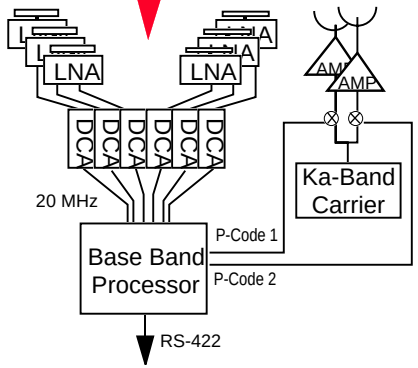
Precision, automated GPS products; system analysis for satellite tracking; automated precision radio metric processing & positioning software.



Advanced GPS flight hardware for autonomous spacecraft navigation



Autonomous, in situ navigation systems design and development

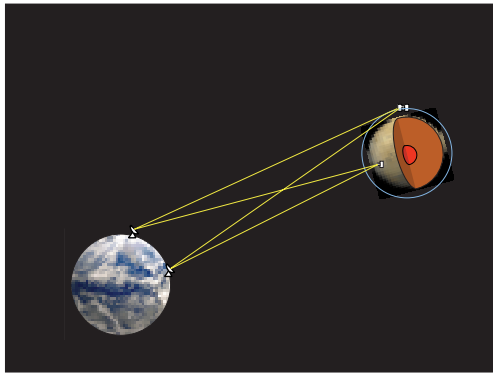


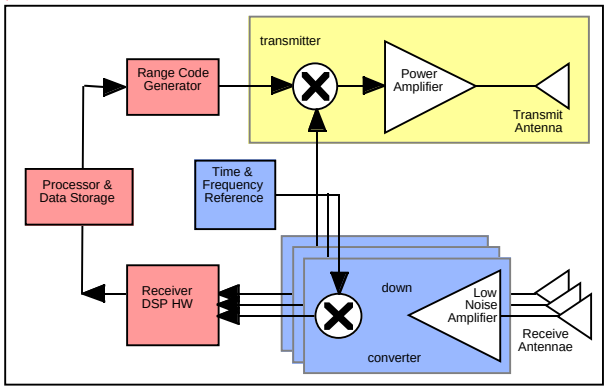
Derivative space flight hardware for autonomous formation flying, relative navigation, and telecom

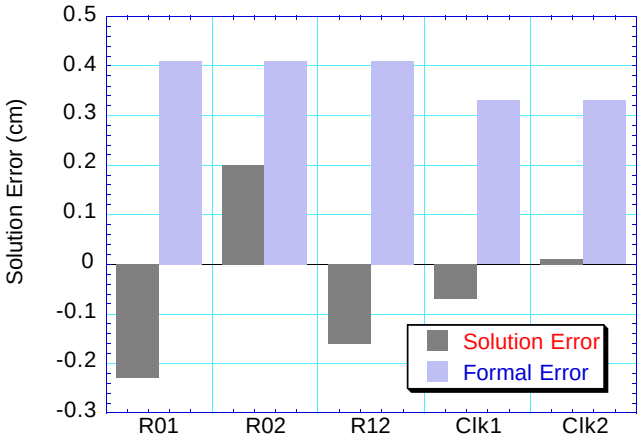
Tracking & telecom technology initiatives for deep space

Radio Metric Tracking
FY98 Q1 Accomplishments

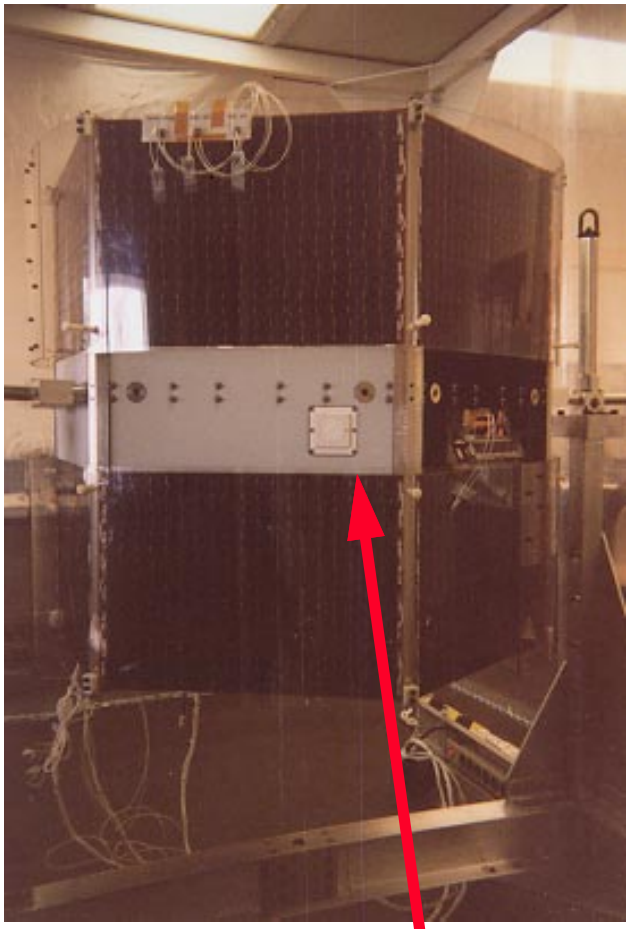
- **Completed acquisition of Galileo VLBI measurements, and successfully acquired same-beam VLBI tracking data from Pathfinder and Mars Global Surveyor**
- **Analyzed Mars orbiter-lander tracking with 2-way Doppler for positioning (1-m level) and Mars orientation estimation**
- **Performed moving platform real-time kinematic positioning experiment with WADGPS commercial partner, and achieved real-time accuracy 60-cm vertical, 30-cm horizontal**
- **Developed a modified design for the Autonomous Formation Flyer (AFF) for DS-3, Mars Ascent Vehicle and Mars Sample & Return scenarios, with option to add telecom**
- **Completed new set of DS-3 AFF tracking studies**





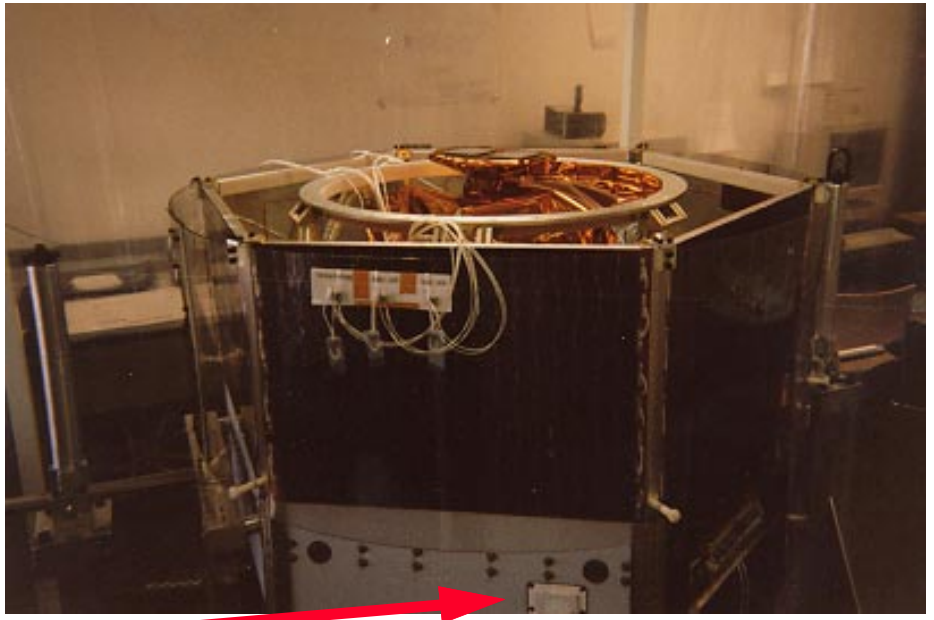


Radio Metric Tracking
FY98 Q1 Accomplishments (cont.)



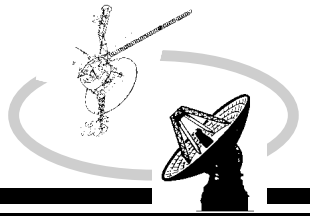
- ✓ Performed final testing of microGPS on the SNOE spacecraft

Currently awaiting anticipated January 23 1998 launch



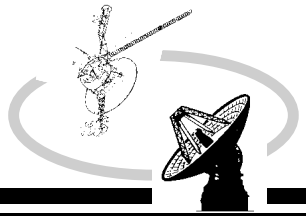
microGPS

Radio Metric Tracking
FY98 Q1 Accomplishments (cont.)



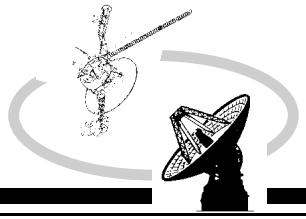
- **Participated in and contributed to Dec 97 NASA GPS technology Roadmap meeting at GSFC.**
- **Submitted two TDA Progress Reports; two more about to be submitted.**
- **Technology Transfer**
  - **New contracts and software licenses developed for TRW, Boeing (Seal Beach), and Analytical Graphics to transfer GPS technology to private sector.**
    - **Currently in progress: OSC, CALGIS, Boeing (Seattle)**
  - **Presently in discussions with potential industry partners for autonomous spacecraft sub-task**
  - **Negotiating with an industry partner for outsourcing the implementation of a global WADGPS network**
  - **In 1st quarter FY98, JPL was approached about use of GIPSY-OASIS for several commercial low-Earth orbiter applications**

Radio Metric Tracking
FY98 Q2 Planned Accomplishments



- **Analyze Galileo VLBI data sets recently acquired**
- **Support and analyze tracking data from three launches:**
  - **SNOE (microGPS)**
    - **SOMO primary sponsor of analysis**
  - **Geosat-Follow-On**
    - **Code Y primary sponsor of analysis**
  - **CRSS (Lockheed-Martin)**
    - **Lockheed-Martin primary sponsor of analysis**
- **Prepare STRV microGPS receiver for delivery in 3rd quarter FY98**
- **Develop and refine AFF design and software to meet needs of New Millennium, Mars, and space interferometry missions**
- **Conduct Mars navigation studies for autonomous GPS-derivative tracking**
- **Submit TDA Progress Report on AFF, and complete AAS conference paper**
- **Perform moving vehicle (automobile) real-time positioning tests using WADGPS in preparation for air and space experiments**
- **Develop and refine plans for global WADGPS system for NASA**

Radio Metric Tracking
Schedule



JPL

Task	FY98 Expanded
	Q1 Q2 Q3 Q4
GPS Calibrations for DSN	TDA Progress Report — Operations (with liens)
GPS-Derivative Navigation	DS-3 DS-4 Mars — TDA Progress Report
Formation flying design study/cost analysis	
Autonomous In Situ Mars Navigation Systems	
microGPS	Delivery
Hardware	
Flight demos	Delayed launch due to launch vehicle availability
GPS Flight Systems	Industry partner
Autonomous navigation GPS receiver	
Global WADGPS system development	Ground demos — NASA SAR plane unavailable
Deep Space Tracking Studies	
Frame tie	
Technology Transfer	
Resources by FY ($K):	600